NATIONAL BUREAU OF STANDARDS REPORT

7441

Progress Report
on

THE DEVELOPMENT OF A RATING METHOD
FOR REFRIGERATED TRUCKS

by
C. W. Phillips
Mechanical Systems Section
Building Research Division

Report to

Transportation and Facilities Research Division
U.S. Department of Agriculture

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT

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February 13, 1962

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Progress Report
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THE DEVELOPMENT OF A RATING METHOD FOR REFRIGERATED TRUCKS

For The Quarter Ending December 31, 1961

by
C. W. Phillips

PURPOSE:

(1) To develop a method for rating refrigerated truck bodies with respect to cooling load, that will take into account the effects of air leakage, moisture weight gain, solar radiation, and air and moisture exchange due to opening of the body doors.

(2) To study a selected number of different types of body construction and insulation as represented by vehicles specially constructed by cooperating manufacturers according to a predetermined schedule.

BACKGROUND:

In an earlier project a rating method for refrigerated trailers was developed to evaluate the cooling load, air leakage and moisture gain of these vehicles intended for long-haul highway transportation of frozen foods.

Certain differences were noted between usage of highway trailers and local delivery trucks which indicated that different test procedures should be used for rating the two types of vehicles.

The highway trailers operate day and night, usually at road speeds, and are opened for loading and unloading only at terminals or major transfer points. The additional cooling load caused by strong solar radiation while the vehicle was stationary was probably less than that caused by air leakage when the vehicle was in motion, and doors are opened infrequently, if at all, during a trip.

Delivery trucks are stationary for the most part, operate primarily during daylight hours, and are subjected to a wide variety of door opening schedules during the working period.

Thus, the rating method for trailers required means for simulating the effect of forward motion, but not solar radiation or door openings. The rating method for trucks, in contrast, requires means for simulating the effect of solar radiation and door openings, but not necessarily the effect of forward motion. It is to be recognized that there are exceptions to the general case.

The Mechanical Systems Section, NBS, Transportation and Facilities Research Division, USDA, and the Truck Body and Equipment Association have, beginning July 1, 1960, sponsored a cooperative effort to develop a suitable method for rating refrigerated trucks taking into account the factors just outlined. The project is being carried out at NBS, under direction of the Mechanical Systems Section.

As in the case of the trailer rating method, standard rating conditions of 100°F ambient temperature at 50% relative humidity and 0°F interior temperature were selected.

A project steering committee was appointed, consisting of representatives from interested industry and government organizations. To date, two meetings of the project steering committee have been held, on October 14, 1960, and on June 19, 1961.

Project accomplishments prior to this reporting period include (1) Assembly of the comparison heater - heat sink apparatus for simultaneous measurement in two ways of the amount of cooling capacity needed to maintain the test truck interior temperature at 0°F. Figure 1 shows some of this equipment. (2) Preparation of the test facilities and instruments needed to conduct the tests and to measure the cooling load and weight gain of the vehicles under study. Figure 2 shows some of the instruments. (3) Measurement of the cooling load, weight gain rate, and air leakage of the first three trucks submitted as test specimens. Figure 3 shows a truck installed for test. Results of these tests were discussed at the June 19, 1961, project steering committee meeting.

Tasks Accomplished During This Reporting Period

Installation was completed of a specially designed perforated ceiling incorporating air volume controlling means to provide draft-free air cooling of the test space when simulated solar radiation tests are made. Figure 4 shows this ceiling. Apparatus to provide simulated solar radiation was designed, constructed and installed, including controls and instruments for regulating and measuring the applied thermal radiation.

The idea of a rotating mechanism to duplicate the effect of the daily sun movement over a vehicle was discarded in favor of adjustable stationary banks of electric heating elements and parabolic reflectors facing each of two sides and the top of a test truck. To simulate the effect of sun movement during the day, the voltage applied to the heaters was varied. Each bank was 9' high and 15' long and consisted of 45 parabolic reflectors 1'x3' at the bank face. Each reflector was equipped with an 81-ohm helical electric resistance coil wound around a 7mm o.d. glass tube mounted in the reflector so that the heater axis was at the focus of the parabolic reflector.

The heating elements were designed so they operated without visible radiation at 208 volts. Maximum heat dissipation of each heater, including both convective losses and radiant transfer, was about 600 Btu/hr per foot of reflector length, or 600 Btu per square foot of projected reflector area. The total heat release of one bank of 45 heaters operating at maximum design voltage would be approximately 83,000 Btu/hr.

Figure 5 shows construction of the individual reflector-heater assembly, and Figure 6 shows the three banks installed in the test room. Also in Figure 6 can be seen two of the three scales used to measure the weight change of a truck under test. Figure 7 shows one of the test trucks in the test room for simulated solar load tests.

Previous observations of truck and trailer skin temperatures exposed to bright summer sunlight at NBS had indicated temperatures as high as 70°F above ambient, and this value was selected arbitrarily as an approximate upper roof skin temperature limit for the simulated solar tests.

To establish a pattern for cyclic variation of the simulated solar energy, values of hourly insolation on a vertical east and west surface and on a horizontal (roof) surface were taken from U.S. Weather Bureau curves, as shown in Figure 8, for June 21 at latitude 40°N. Such a solar day extends from 4:40AM to 7:20PM, with maximum insolation values of 235 Btu/hr (Ft^2) on a vertical east wall at 7:30AM and on a vertical west wall at 4:30PM, and 320 Btu/hr(Ft^2) on a horizontal surface at noon.

The wavelength of maximum emission of thermal energy is a function of the temperature of the emitting source and is between 0.3 and 0.7 micron for sunshine at the earth surface, depending on the effect of the atmosphere.

The measured temperature of one of the heater rods operating at the maximum voltage necessary for test was 700°F. At this temperature the wavelength of maximum emission is about 4.5 micron. As the voltage is lowered, the temperature of the heater approaches the ambient temperature of 100°F, at which temperature the wavelength of maximum emission is about 9.3 micron. The significance of selecting a radiation source at temperatures of 700°F or lower is related to the capacity of various surfaces to absorb radiant energy. Surfaces covered with nonmetallic paint, such as most truck bodies, regardless of color, will absorb about the same fraction of radiation at the wavelengths above 4 microns as dark-painted surfaces will absorb at the shorter wavelengths of solar radiation. For this reason it was considered unnecessary to repaint any of the painted vehicles in order to establish similar conditions for the simulated solar tests. Metallic surfaces such as aluminum or stainless steel, or metallic-painted surfaces would require special consideration. All the vehicles received to date for the test series have been painted with nonmetallic paints.

For these tests it was desired to determine the effect of similar solar insolation, regardless of the finish of the test vehicle, on the various types or methods of construction of the various truck bodies in the test series. By using the lower temperature longer wavelength radiation source for the simulated solar tests, all vehicles tested should absorb radiation as if they were painted with dark paint and exposed to solar radiation of equal intensity. It was not an intended purpose of these tests to determine what type of surface treatment was the best for minimizing the heat gain due to solar exposure.

Earlier tests at NBS of insulated metal covered panels exposed to sunlight have shown that gloss-white enamel surfaces were more effective than bright mill-finish aluminum or stainless steel surfaces in reducing the rise in skin temperature due to solar radiation. Some dark-painted surfaces were of similar effectiveness as the metallic surfaces in limiting the skin temperature rise due to solar heating. An examination of the emissivity factors for various surfaces at various wavelengths explains this. Depending on their brightness, metallic surfaces will absorb from 10 to 65 percent of the energy at the short wavelengths of sunshine compared to an absorption ranging from 65 to 80 percent for dark-painted surfaces at the same wavelengths.

For longer wavelength radiation, metallic surfaces at a temperature of 100°F, again depending on brightness, are capable of radiating from 10 to 30 percent as much energy as a perfect black radiator, while dark-painted surfaces can radiate from 85 to 95 percent as much energy as a perfect black radiator.

Of the radiant energy absorbed by a surface over insulation such as an insulated truck wall, only a small percentage will actually be transferred through the insulation; while a high percentage of the energy will be radiated to surrounding lower temperatures or given up to convective air movement at the surface. The metallic surfaces absorb less solar energy than the dark painted surfaces but in turn are less able to radiate the energy which they do absorb tending to minimize the difference in the amount of energy transmitted through the surface. As each surface is heated above ambient air temperature, it loses additional heat to convective air currents in proportion to the difference in temperature between the surface and the air.

Although most of this reporting period was utilized in completing the construction and adjustment of the simulated solar apparatus, simulated solar heat gain tests were completed on one of the trucks previously measured for heat gain without solar load. This truck was identified in earlier reports as truck "C".

The maximum observed increase in measured heat transmission caused by the simulated solar heating for this truck was about 16 percent averaged over a four-hour period with the peak occurring about four hours after noon of the simulated solar cycle. Figure 9 shows the average relationship between the time of the simulated solar cycle and the measured heat gain for several daily cycles. Figure 10 shows the average temperature of the two sides and roof before, during and after a simulated solar cycle. The temperatures shown are the average of eight thermocouples each on the east wall and roof, and seven thermocouples on the west wall. Each thermocouple, representing an equal area, was attached to the exterior of the surface by soldering, after which the area affected by soldering was painted to match the original surface. The west wall had one less thermocouple included in the average because the brine lines for the cooling coil entered the wall so close to one thermocouple that it was not indicative of normal skin temperature.

Radiation measurements were made with three special radiometers, one mounted near to and parallel to each of the three surfaces affected by the simulated solar energy. These measurements are being analyzed for possible use in establishing criteria for duplicating the simulated solar tests on other vehicles and in other test laboratories. Also under study are measurements of two other devices used to interpret the intensity of the net radiant energy directed toward the vehicle skin during a simulated solar cycle.

At the close of the reporting period the first vehicle was being removed from the test facility, and a second vehicle, Truck "A" in earlier reports, was being prepared for installation for simulated solar tests.

During this reporting period some additional work was done in modifying and refining the helium-trace measuring instrument to be used to measure the air exchange due to various door-opening schedules. Preliminary tests have indicated that the helium-trace technique can be used for this measurement. Figure 11 shows the instrument and sensing element as it appeared prior to the most recent modification to reduce the number of adjustment dials required for operation.

The fourth vehicle to be studied in the project series, an ice cream truck furnished by the Hackney Company, Wilson, North Carolina, was received in December. This vehicle is insulated with foamed-in-place polyurethane.

FUTURE PLANS:

Simulated solar heat gain tests will be performed on some of the other vehicles on hand for study.

The study of air exchange during various door opening schedules, using the helium-trace instrument will be started.

Study of suitable means for measuring the effective radiation intensity will be continued and the techniques for measuring the additional refrigerating capacity required by various door opening schedules will be investigated.

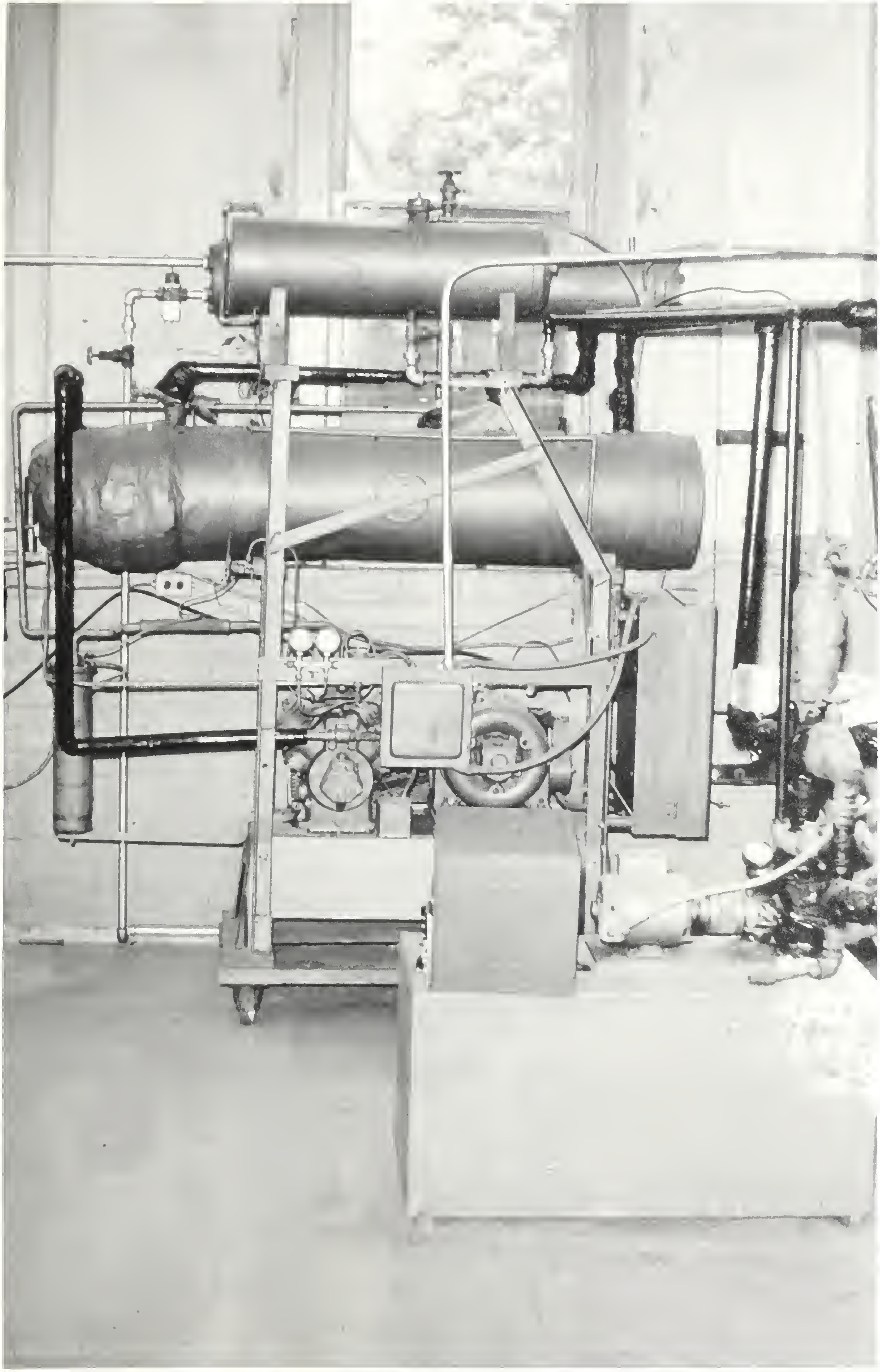

Figure 1

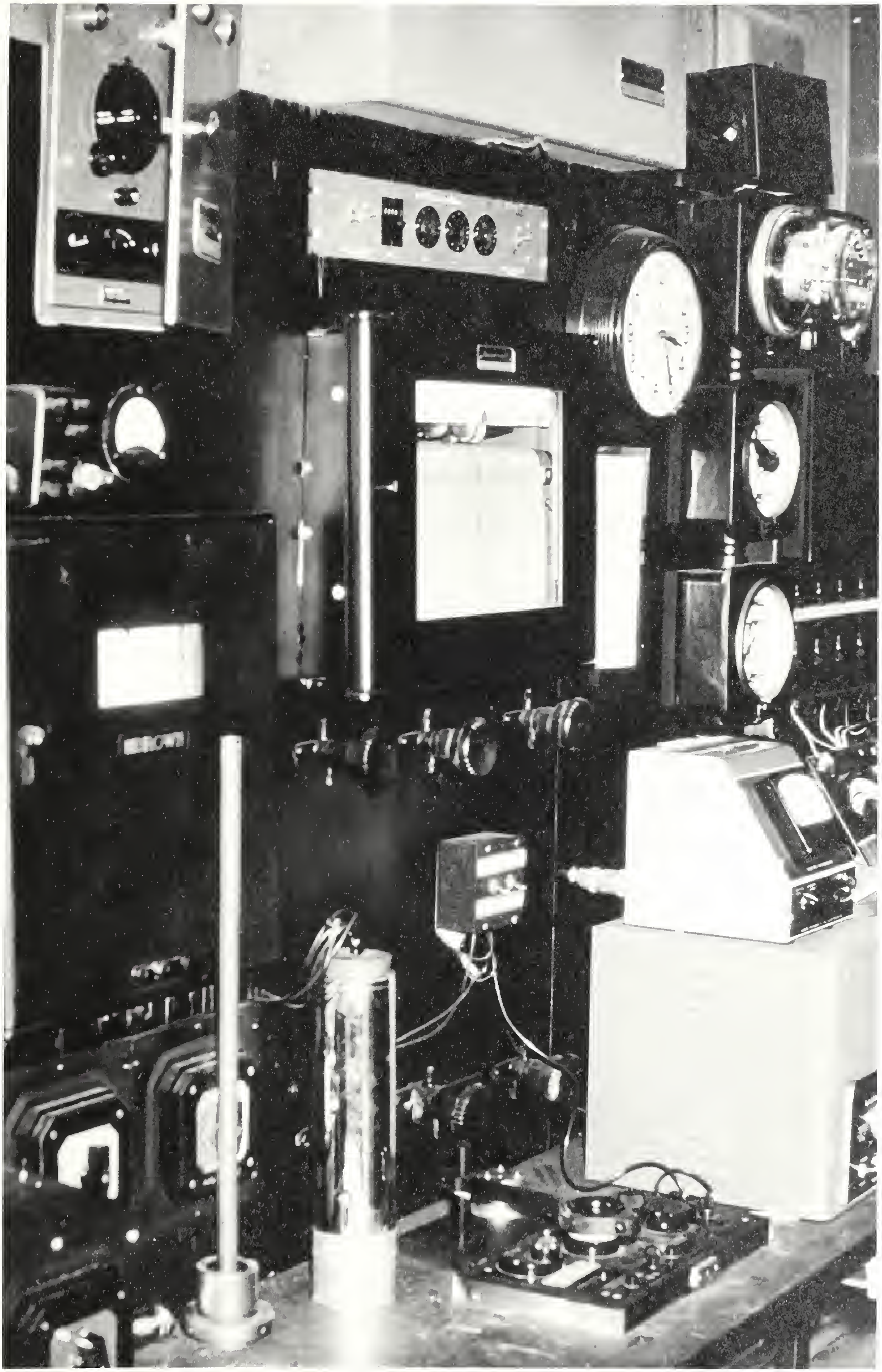

Figure 2

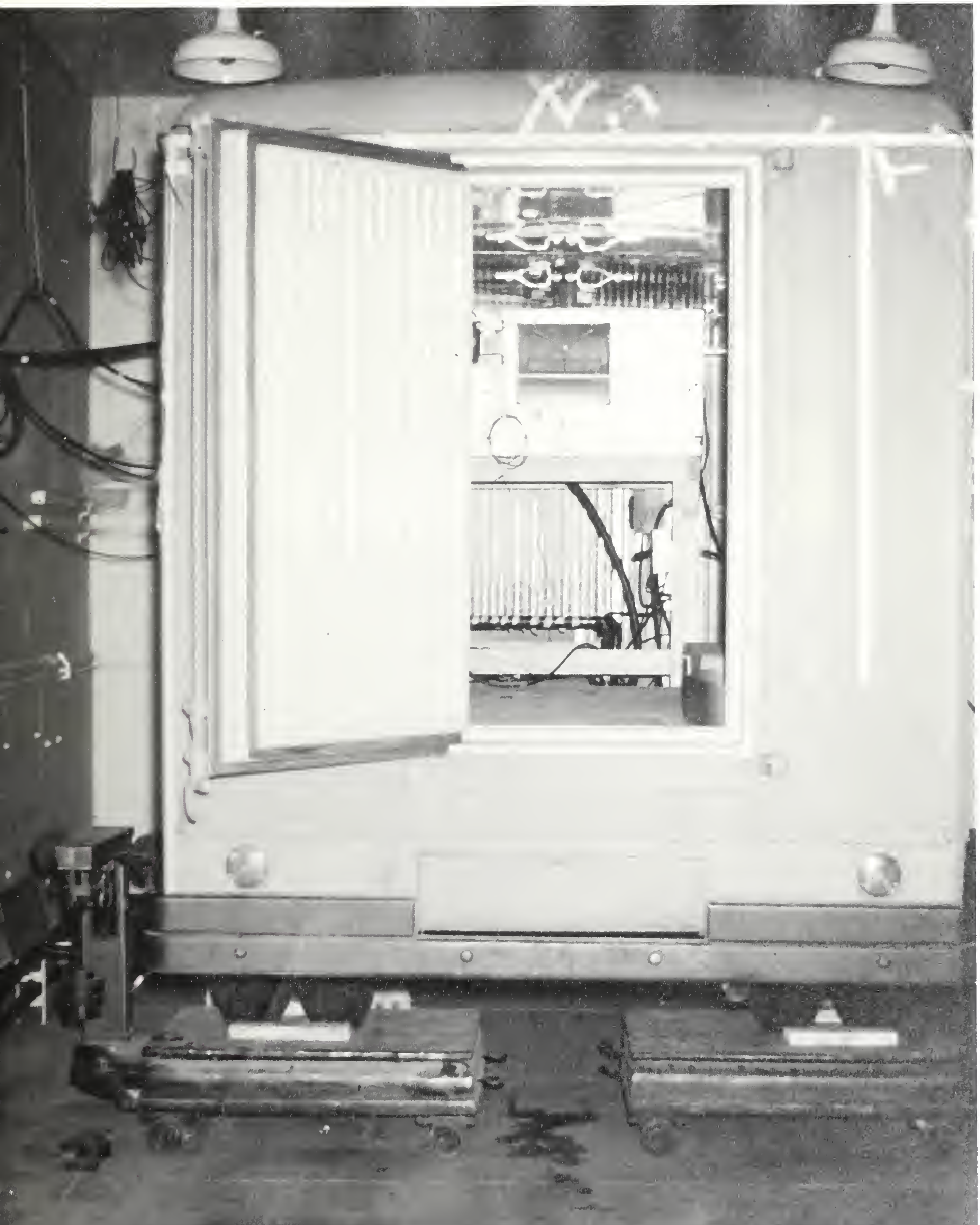

Figure 3

Figure 4

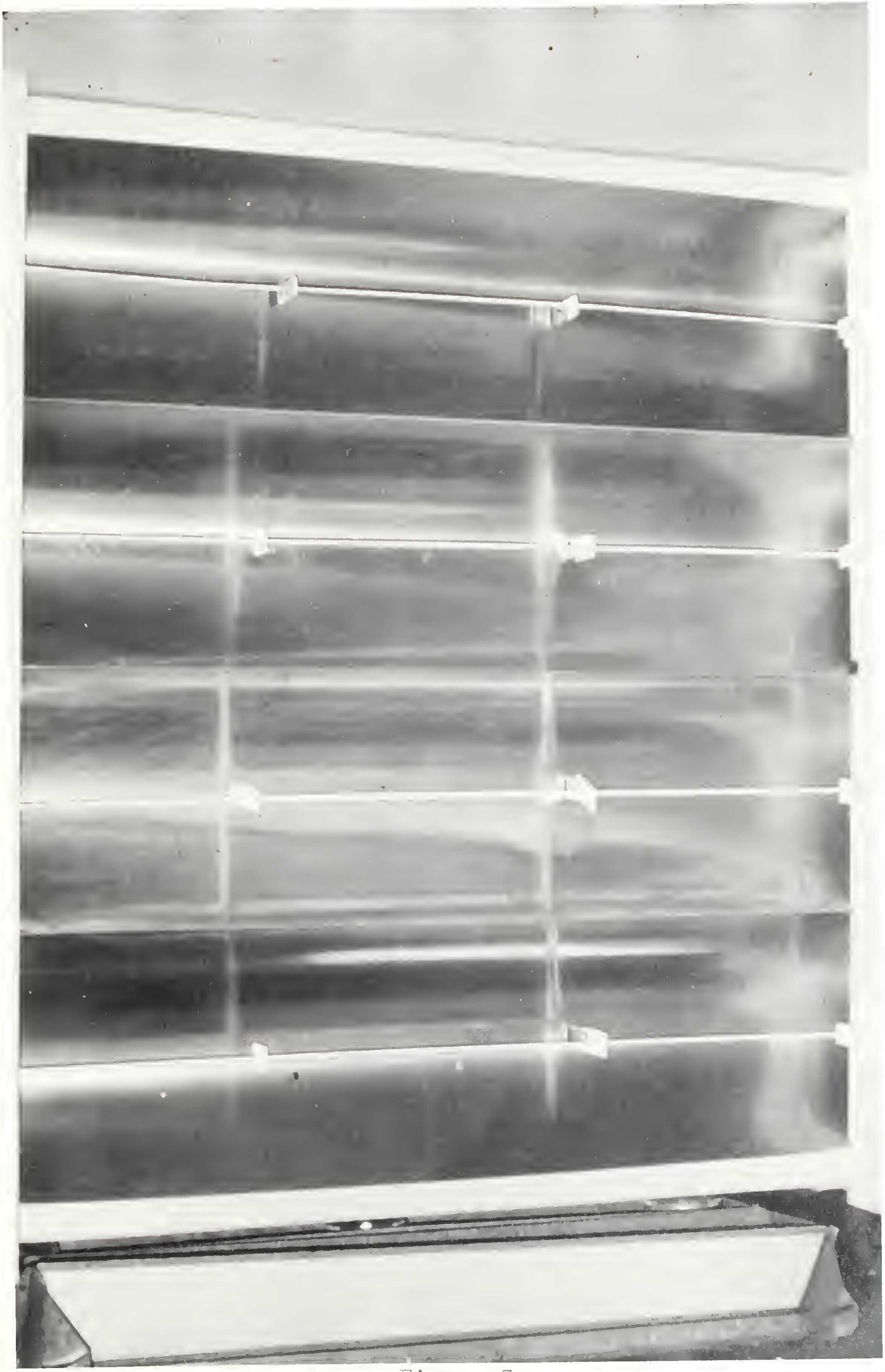

Figure 5

Figure 6

Figure 7

3c 36c

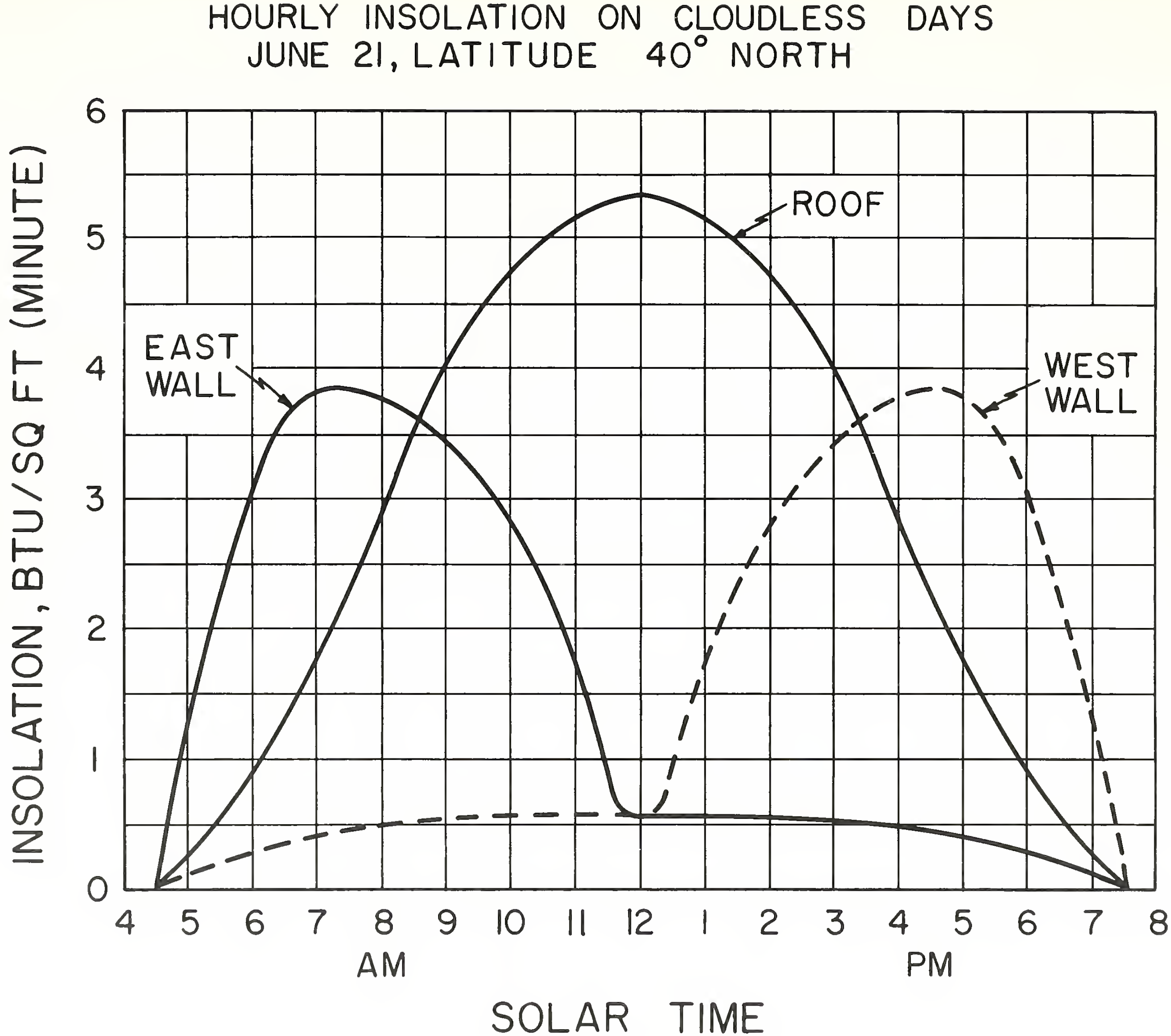
HOURLY INSOLATION ON CLOUDLESS DAYS
JUNE 21, LATITUDE 40° NORTH
INSOLATION, BTU/SQ FT (MINUTE)
6
5
4
3
2
1
0
EAST
WALL
ROOF
WEST
WALL
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
AM
PM
SOLAR TIME

Figure 8

INCREASE IN COOLING LOAD CAUSED BY SIMULATED SOLAR CYCLE
(AVERAGE OF TWO CONSECUTIVE TESTS)

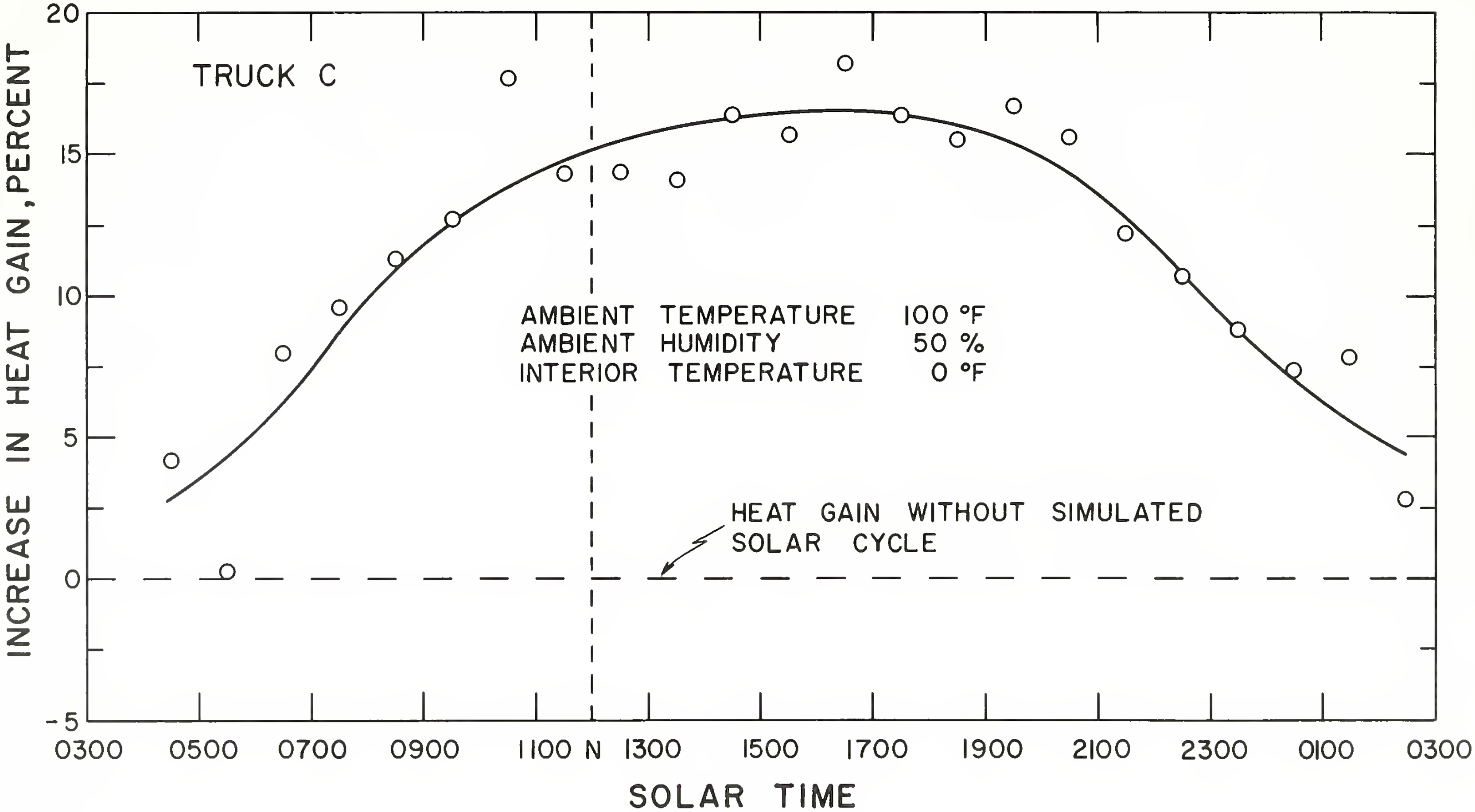

Figure 9

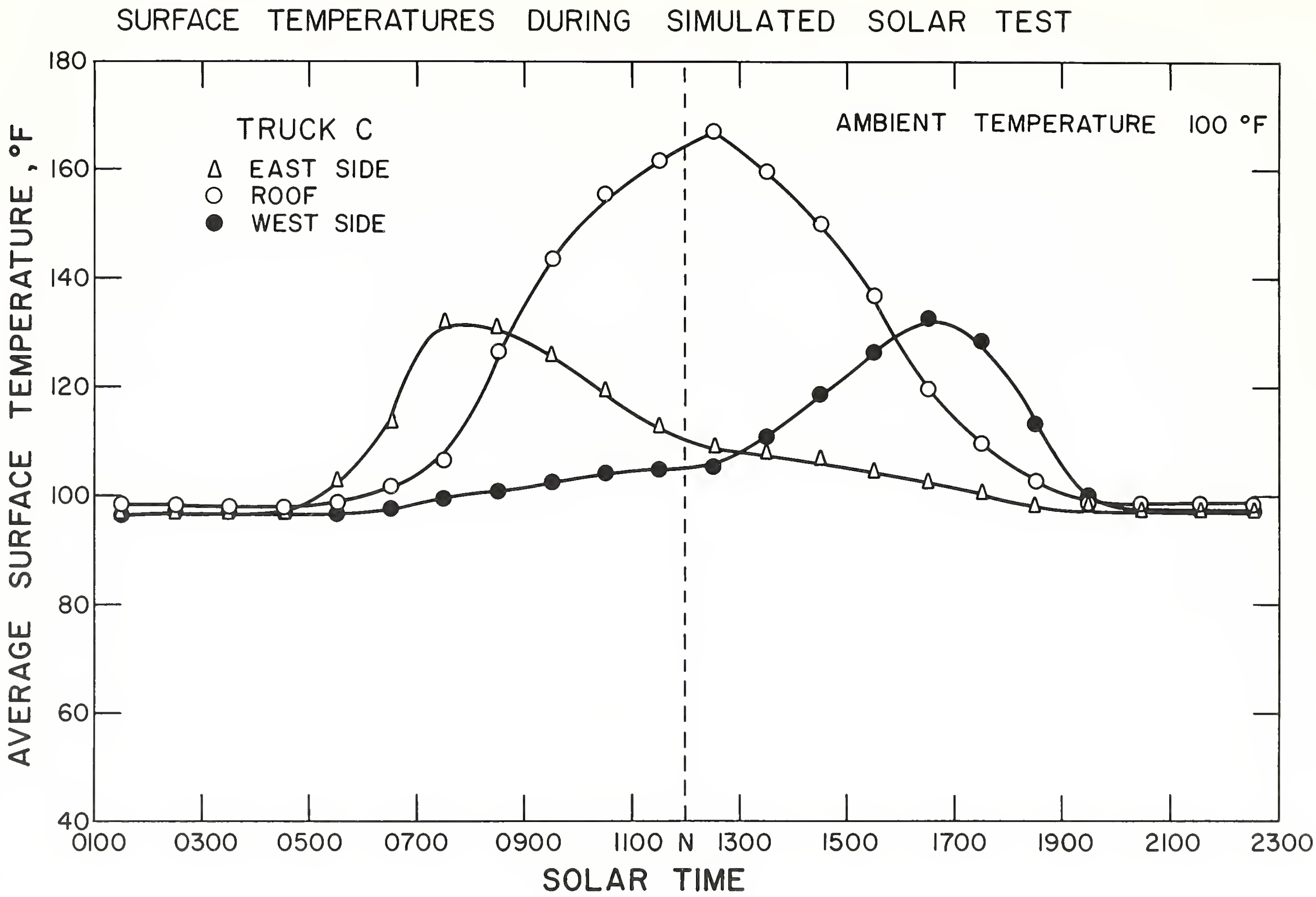
SURFACE TEMPERATURES DURING SIMULATED SOLAR TEST
TRUCK C
Δ EAST SIDE
○ ROOF
● WEST SIDE
AMBIENT TEMPERATURE 100 °F
AVERAGE SURFACE TEMPERATURE, °F
180
160
140
120
100
80
60
40
0100
0300
0500
0700
0900
1100 N
1300
1500
1700
1900
2100
2300
SOLAR TIME

Figure 10

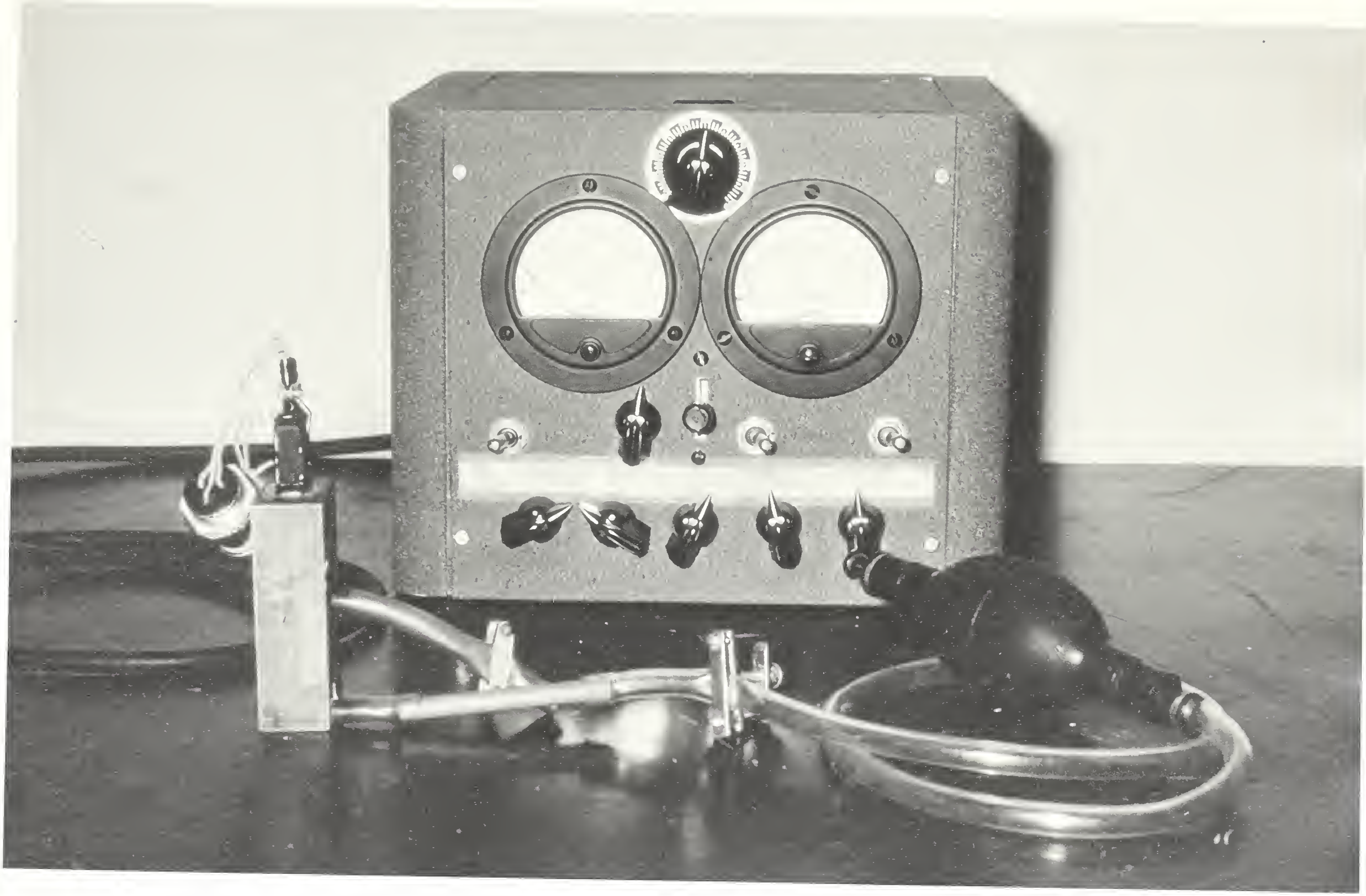

Figure 11

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Suhstances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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